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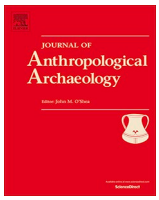

The organization of production for Inka Polychrome pottery from Pachacamac, Peru

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ABSTRACT

This study investigates the organization of production for Inka Polychrome pottery used at the Temple of the Sun, Pachacamac. Inka Polychrome pottery was critical to imperial strategies for managing state power in the provinces. It was highly standardized in appearance yet is known to have been produced at many locations throughout the empire by Inka and subject potters. Pachacamac was an important political and ideological location on the central coast that was transformed by the Inka after C.E. 1470 into a major imperial center. To evaluate the production and source of pottery at Pachacamac, a sample of 149 ceramics in local, Inka Polychrome, and Regional Inka styles were evaluated using neutron activation analysis to identify compositional groups. Attributes related to the production and decoration of these ceramic artifacts were recorded and statistically compared between groups. Compositional data from this analysis was also compared to compositional data from ceramics excavated from other South American sites and analyzed at the Lawrence Berkeley National Laboratory. Results found that multiple groups of potters at multiple places (some of which are local) produced this pottery, and small amounts of pottery are being imported.

1. Introduction

Material culture is a key component of many strategies used by empires in the creation and maintenance of state power among their subjects. In larger territorial empires, this production is not consolidated in the imperial core but is decentralized and, in the case of the Inka empire, done in part by subject artisans. In the Inka empire, material culture in imperial styles, especially Inka Polychrome pottery, was standardized in design and form, despite this diverse production. This research asks the question: how was the production of Inka Polychrome pottery organized? To address this question, attribute analysis was combined with neutron activation analysis for 149 ceramic artifacts from the site of Pachacamac on the central coast of Peru. Pachacamac had a long history of occupation and use and was a major Inka provincial center after around C.E. 1470. Both Inka and local decorative styles of pottery were analyzed to determine if this pottery was produced locally or elsewhere, and how the potters who produced it were organized by the Inka state.

2. Background

In the Late Horizon (C.E. 1400–1532), *Tawantinsuyu*, "the land of the four corners" and the empire of the Inkas, expanded rapidly across Andean South America to encompass roughly 2 million km^2 and an estimated 12 million subjects belonging to around 80 different subject polities (D'Altroy, 2015; Morris and von Hagen, 2011). Strategies of managing these subjects, and the degree of Inka investment and presence, varied from place to place (Alconini, 2008; D'Altroy, 1992). Though the relationships of subjects with the state varied widely, there were some commonalities of inclusion in the Inka empire that were rooted in the Andean ideal of reciprocity. These were the Inka's requirement of labor as tribute from subjects, and gifts given to subjects by the Inkas, either in feasts and rituals where food and drink were provided (Hastorf, 2007) or as prestige goods given to local elites (Costin and Earle, 1989; Lau, 2019; Murra, 1980). These both required objects made in imperial styles, including textiles, metalwork, and pottery.

Inka material culture was decorated in distinct, recognizable imperial styles, with motifs shared across multiple media. Inka Polychrome pottery, a ubiquitous part of the imperial material assemblage, was highly standardized and produced with a limited number of forms and designs (Bray, 2003:123; Fernández, 1971, Meyers, 1975; Rowe, 1944). These objects communicated the Inka empire's power and hospitality (Morris, 1991). Material objects in imperial styles play an important role in the statecraft of empires worldwide, as a means of communicating state power and connecting subject populations to the

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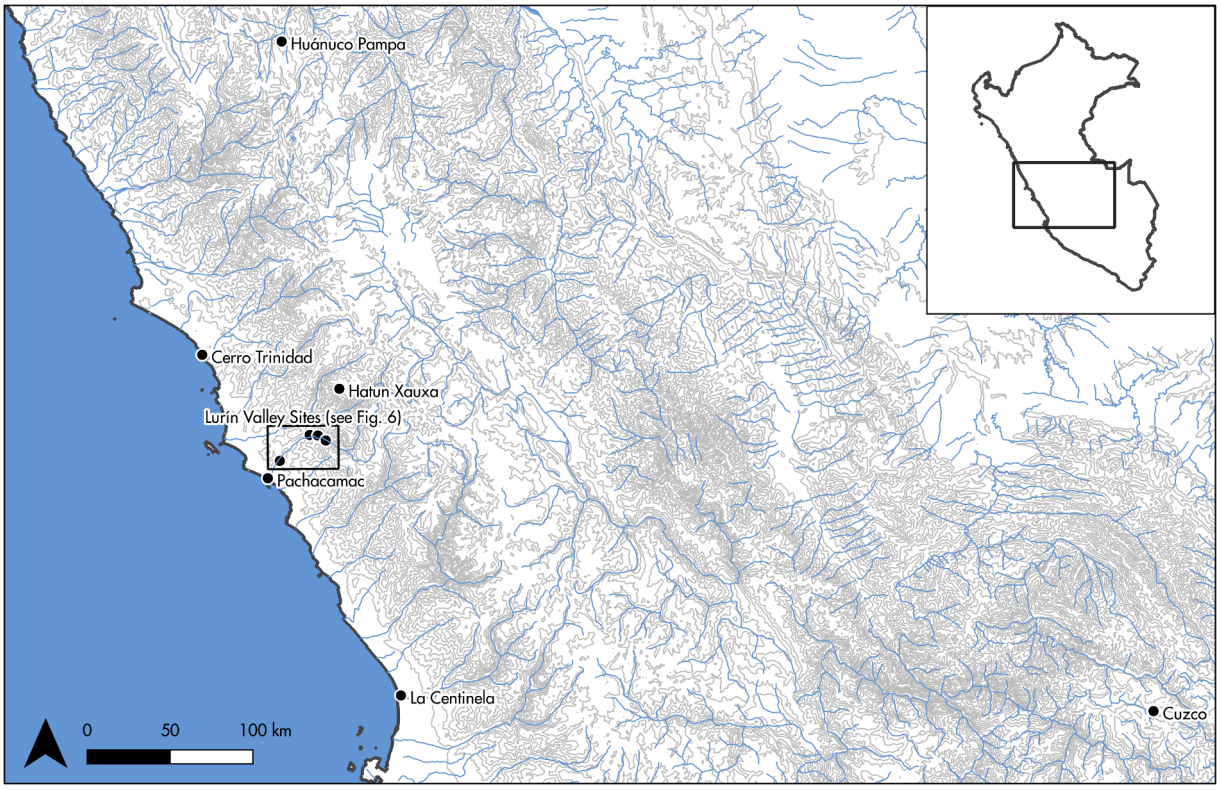

Fig. 1. Map of Peru with Pachacamac and other sites mentioned in the text.

state (Boozer, 2010; Bray, 2018; D'Altroy, 2018; Khatchadourian, 2016; Sinopoli, 2003). Ethnohistorical and archaeological evidence indicates that these objects were produced by subjects serving their state-mandated labor requirements either near their home communities or as *mitmaq*—subjects permanently relocated to different parts of the empire to serve state needs (Alconini, 2013; Cremonte et al., 2015; Espinoza Soriano, 1970; Espinoza Soriano, 1983; Hayashida, 1998; Murra, 1980; Spurling, 1992; Williams and Lorandi, 1986). Inka pottery also moved around the empire, typically in short distances (Alconini, 2013), but sometimes to far-flung locations (Bray et al., 2005). How, then, did the Inka organize the production of this pottery, which was highly standardized, instantly recognizable, and produced and distributed widely? To address this question, I examine the organization of production for Inka Polychrome pottery from Pachacamac, Peru.

Pachacamac occupies around 500 ha where the Lurín River meets the Pacific Ocean on Peru's central coast (Fig. 1). Its occupation dates to at least the Early Intermediate Period (C.E. 200–600) (Franco and Paredes, 2016). During the Late Intermediate Period (C.E. 1000–1400), Pachacamac was the home of a powerful oracular non-human being or *wak'a* which was consulted by individuals from across the empire, including the emperor, or *Sapa Inka* (Curatola, 2008, 2015). Pachacamac was also the political center of the Ychsma polity, a hierarchical society centered on the Lurín and Rimac valleys (Eeckhout, 2013; Marcone, 2010; Marsteller et al., 2017; Shimada, 1991). When it was subjugated by the Inka around CE 1460–1470 (Marsteller et al., 2017), Pachacamac received a high level of imperial investment because of its importance (Marcone, 2010). This included the renovation of existing structures and the construction of new ones (Fig. 2; Franco, 1996; Marcone, 2004, 2010; Marcone and López-Hurtado, 2002; Sánchez, 2000; Shimada, 1991; Shimada et al., 2010; Tiballi, 2010:97) so that Inka-sponsored activities promoting the state's power and interests, including feasts, rituals, and ceremonies, could be enacted (Coben, 2006, 2012).

For this research, statistical analyses of quantitative and qualitative attributes of 149 ceramic artifacts are combined with characterization data from neutron activation analysis (NAA). The ceramic artifacts included in this study were excavated from a midden on the southeastern face of the Temple of the Sun. They include Inka Polychrome Pottery and the contemporary and preceding local styles of Ychsma and Lima pottery (Segura Llanos, 2004; Vallejo Berríos, 2004; Vallejo Berríos, 2011). Local styles are used to compare the elemental composition between Inka Polychrome pottery and pottery styles that originate in the region. NAA data are also compared to data on Peruvian ceramics from the Lurín valley and Cuzco that were analyzed at the Lawrence Berkeley National Laboratory (LBNL) and are published through the Digital Archaeological Record (tDAR) (Boulanger, 2012, 2013, 2016).

2.1. Inka pottery

It is important to distinguish between Inka pottery—that is, all pottery used by the Inka in the production of state-sponsored activities—and Inka Polychrome pottery. Inka Polychrome is highly standardized and adheres to specific canons of form and design. Many "hybrid Inka," "regional Inka" or "local Inka" styles existed throughout the empire that combined local manufacturing traditions with either the forms or designs of Inka Polychrome. Originating in the Cuzco basin, Inka Polychrome pottery was produced in a few set forms of varying size (Fig. 3; Bray, 2003) and decorated with a limited suite of primarily geometric designs applied in specific locations (Fernández, 1971), though variations did exist. It is visually distinctive and highly recognizable. Some of these forms ranged widely in size. For example, *urpus*, also known as "aríbalos," a long-necked pointed-bottom vessel with a flaring rim used for serving *chicha*, a maize beer (Hayashida, 2019), have been found at Pachacamac as miniature vessels less than 10 cm, and as large vessels over a meter in size. Of the suite of forms for Inka Polychrome pottery, only a few are frequently seen in provincial locations (Bray, 2003). These include serving vessels such as plates, bowls, and *urpus*. The designs on Inka Polychrome were generally geometric, repeating, abstract, and in some instances shared with other media (Bray, 2018; Cummins, 1993). These designs may have been

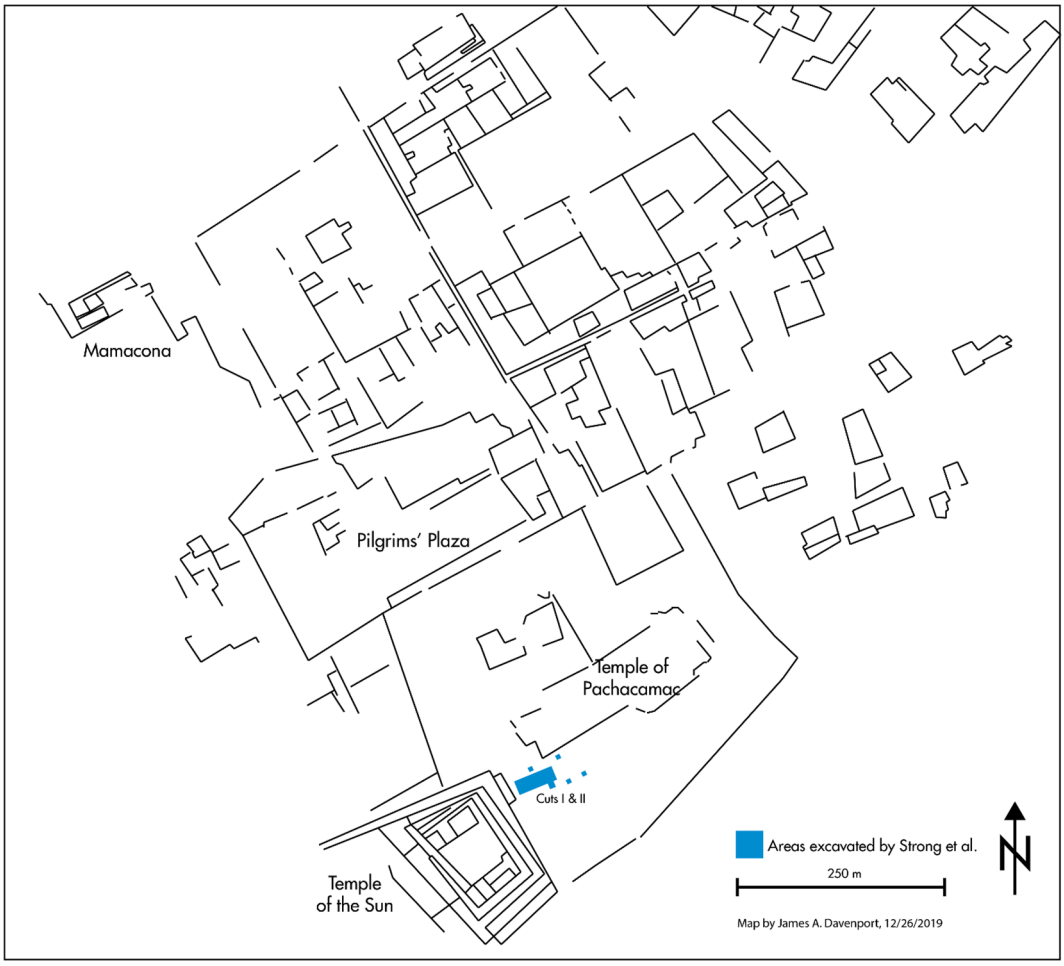

Fig. 2. Map of the ceremonial core of Pachacamac with notable structures and places labeled. The location of Strong et al.'s excavations in 1941 is also identified.

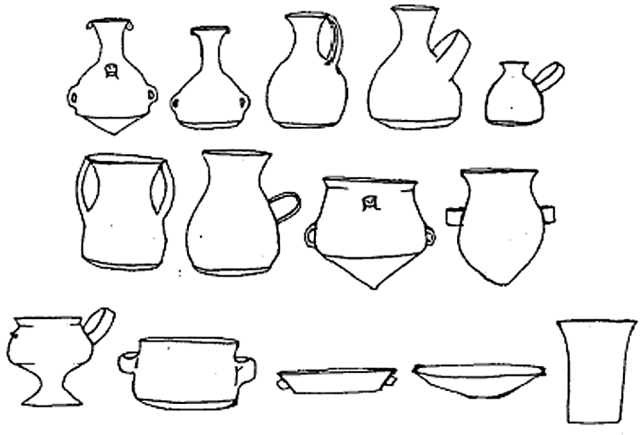

Fig. 3. Standardized forms of Inka Polychrome pottery. After Meyers (1975).

communicative (Cummins, 1993) or empowered the pots as non-human agents in imperial strategies of control (Bray, 2017). It has been suggested that the decorations of Inka Polychrome pottery could transmit information as a semasiographic system (Cummins, 1993), reflect the Andean worldview (Allen, 2015) or correspond with geographical or political units within the empire (Cummins, 2007).

Recent research into Inka pottery production (e.g., Alconini, 2013; Costin, 2016, 2018; Gotliko et al., 2016; Hayashida, 2019; Páez and Sardi, 2014; Williams et al., 2016) and Inka ceramic workshops (D'Altroy et al., 1998, 2007; Donnan, 1997; Hayashida, 1995, 1998, 1999; Lorandi, 1991; Mackey, 2003; Quave, 2012, 2017; Spurling, 1992) has greatly expanded our knowledge. Workshops varied in organization and scale, and multiple types with different purposes existed (Zasada, 1985), to provision, for example, state-sponsored feasting events (Mackey, 2003), elite palace contexts (Quave, 2012, 2017) or provincial administrative centers (Hayashida, 1995, 1998, 1999; Lorandi, 1991). At some locations pottery was centrally produced and distributed to nearby settlements (Alconini, 2013; Cremonte et al., 2015; Williams et al., 2016). While much Inka pottery was produced locally (e.g. Williams et al., 2016), small amounts of Inka Polychrome pottery traveled between major Inka centers (D'Altroy and Bishop, 1990) and in some cases, like the *qhapaq hucha* mountaintop sacrifices, pottery sourced to disparate locations in the empire was found together (Bray et al., 2005). Through the *qhapaq ñan* road system, pottery and other goods could be transported great distances (Jenkins, 2001). Standardized plates and bowls were stackable and more easily transported than closed forms (D'Altroy and Bishop, 1990).

2.2. Pachacamac

At the time of Spanish conquest, Pachacamac was a major Inka center on the central coast of Peru. It was the location of an important oracular *wak'a* consulted by Inka emperors and the destination for pilgrimages from across the empire (Curatola, 2015). In the Late Intermediate Period, Pachacamac was the center of the Ychsma polity, which was centered on the Lurín and Rimac valleys (Marcone, 2010; Marsteller et al., 2017). Ychsma pottery is present throughout the central coast and was likely made using several clay sources in these

valleys (Makowski et al., 2015). After Pachacamac was subjugated, the Inkas completely renovated the site's ceremonial core, constructing the Pilgrim's Plaza, the Mamacona convent, and the Temple of the Sun (Fig. 2; Franco, 1996; Makowski, 2015; Marcone, 2004, 2010; Marcone and López-Hurtado, 2002; Sánchez, 2000; Shimada, 1991; Shimada et al., 2010; Tiballi, 2010). This renovation was likely the most monumental by the Inka on an existing layout (Hyslop, 1990) and was motivated by the cultivation of coca in the *chaupi yunga* of the Lurín valley (the piedmont zone between the dry coast and the Andes), the pan-regional influence of the *wak'a* (Cornejo, 2000, 2002; Marcone, 2010; Rostworowski, 1999) and the large amount of tribute it received from pilgrims (Urton, 2015).

Inka spaces at Pachacamac were used for state-sponsored rituals, ceremonies, feasts, and events. The Temple of the Sun was the second-most important religious structure in the empire after the principal sun temple, the *Qorikancha* in the capital Cuzco (Cobo, 1990 [1653]). The Mamacona convent was a building where *aqlla* ("chosen women" taken as children from conquered groups who produced textiles, food, and drink for ceremonies at Sun Temples) lived, produced crafts, and carried out state-sponsored rituals (Cieza de Leon, 1864a:87; Cobo, 1990[1653]:89; Covey, 2008; Tiballi, 2010; Vega, 1961:80). The events that occurred in these spaces required Inka style objects, including Inka Polychrome pottery. Were these objects made at Pachacamac, or brought there from other Inka centers?

Investigations into textiles from Pachacamac show that Inka-style textiles made with local materials were produced using different technological styles, and textiles were also produced using non-local materials (Frei and Bjerregaard, 2017; Tiballi, 2010, 2014). Evidence for local production of other imperial style textiles may lend support for the local production of Inka Polychrome pottery as well. Citing ethnohistoric documents, Hyslop writes that only a few areas in the empire (including the area around Pachacamac) had artisans capable of "replicating state ceramics with extreme accuracy" (1993:341). A recent study of pottery from the Lurín valley using laser ablation-inductively coupled plasma-mass spectrometry (LA-ICP-MS) to analyze clays (Makowski and Oré, 2014; Makowski et al., 2008, 2015) found three distinct compositional groups, and each group was comprised of Ychsma and Inka styles. Each group contained multiple macroscopically defined paste groups as well. This study also found similarities between these groups and raw clay sources in the Lurín and Rimac valleys.

3. Research questions

Inka Polychrome pottery played an essential role in the imperial project, facilitating the reciprocity necessary to manage relationships with subjects. While there have been many recent studies about pottery production in the Inka empire, the distinctive Inka Polychrome pottery remains less understood, especially in provincial locations. Inka Polychrome pottery was highly standardized, yet its production was decentralized and occurred throughout the empire. In established Inka provincial centers, the occurrence of Inka polychrome pottery is low. Inka Polychrome pottery makes up just 2.13% of the assemblage from Huánuco Pampa (Morris et al., 2011:227) and 8% of the assemblage from Hatun Xauxa (Costin, 2002:211), two important Inka provincial centers. In contrast, 30% of the Sun Temple assemblage is Inka Polychrome (Strong et al., 1943). These contexts and excavations are not directly comparable due to differences in scale, scope, methods of excavation, and locations and contexts within these sites. Nonetheless, Pachacamac is a provincial location where Inka Polychrome pottery is found in abundance, and understanding the production organization of this pottery will provide valuable information about the Inka political economy and how the Inka met the need for this essential craft. To understand the organization of this production, this research addresses several related questions. First, was Inka Polychrome pottery produced locally at Pachacamac or elsewhere in the lower Lurín valley? Second, were there multiple loci of production for Inka Polychrome pottery, and if so, are there discernable decorative differences in pottery from different production origins? Finally, how does the assemblage of Inka Polychrome pottery relate to other sites in the Lurín valley? To address these questions, NAA combined with statistical analysis of attributes are applied to a sample of Inka Polychrome and local styles of pottery excavated from a midden on the Northeast Face of the Temple of the Sun at Pachacamac (Fig. 2).

4. Materials and methods

4.1. Sample

This study utilizes artifacts from a historic excavation that are currently curated in museum collections. While the excavation was not designed with this research in mind, nor was it carried with modern best practices, this collection is still a valuable repository of information for Andean archaeologists. There are extensive archaeological collections in museums in North and South America and Europe which have great potential for new inquiries into past cultures (Carmichael, 2020; Gotliko et al., 2016).

The study sample was recovered between July 23 and October 10, 1941, in an excavation led by William Duncan Strong (Strong et al., 1943). The project was supported by the Institute of Andean Research. The team included Strong, his then graduate student Gordon Willey, and John M. Corbett. The goal was to build upon the work of Max Uhle (1991 [1903]). Forty-four years prior to Strong's work, Uhle mapped much of the ceremonial core of Pachacamac and excavated at several areas throughout the site, establishing a chronological ceramic sequence for the central coast. By digging at a midden at the Inka-constructed Temple of the Sun, Strong hoped to uncover an uninterrupted ceramic sequence with all of the types identified by Uhle. Strong excavated a trench roughly 24 m long, 12 m deep, and 8 m across (Figs. 4 and 5). The first portion of this trench, "Cut 1," was removed all at once, and then "Cut 2" was removed along the southern wall of Cut 1. Despite the presence of clearly defined stratigraphic layers, Cut 2 was removed in 1 m square and ½ meter deep "blocks" (Strong et al., 1943:44). Strong and his team excavated a total of 24,038 ceramic artifacts, of which 4119 were diagnostic. While some undiagnostic material was discarded in the field, the majority of this material is currently curated at the American Museum of Natural History in New York.

Strong did not identify a complete, uninterrupted sequence of ceramic types in the trench, but rather uncovered two distinct contexts: the first was a midden dating to the Late Horizon which corresponded to the use of the Temple of the Sun, and the second was a cemetery dating to the Early Intermediate Period, from which over 100 individuals were removed. In their analysis of the ceramic artifacts, the authors identified three style categories, some of which contained subgroups. The first category, "Inca," contained forms and designs that are identified today as Inka Polychrome pottery. The second category, "Inca-Associated," was the term used for material in the more recent context which was not Inka Polychrome. This included local Ychsma styles as well as other contemporary styles used by the Inka, such as blackware from the north and south coasts of Peru and Chancay black-on-white originating in the north-central coast of Peru. "Inca-Associated" also contained hybrid Inka pottery which combined elements of Inka and regional styles. "Interlocking," a term coined by Kroeber (1926) in a study of Uhle's ceramics from Cerro de Trinidad in the Chancay valley, was the third category. It included all the material from the earlier context and now is better classified as Lima and Nievería styles, though other styles are present as well. The distinction between the two contexts is evident when the frequencies of the different categories by excavation block are plotted (Fig. 5). While the assignment of ceramics into these categories was mostly correct, poor control over stratigraphy and a still-developing understanding of these

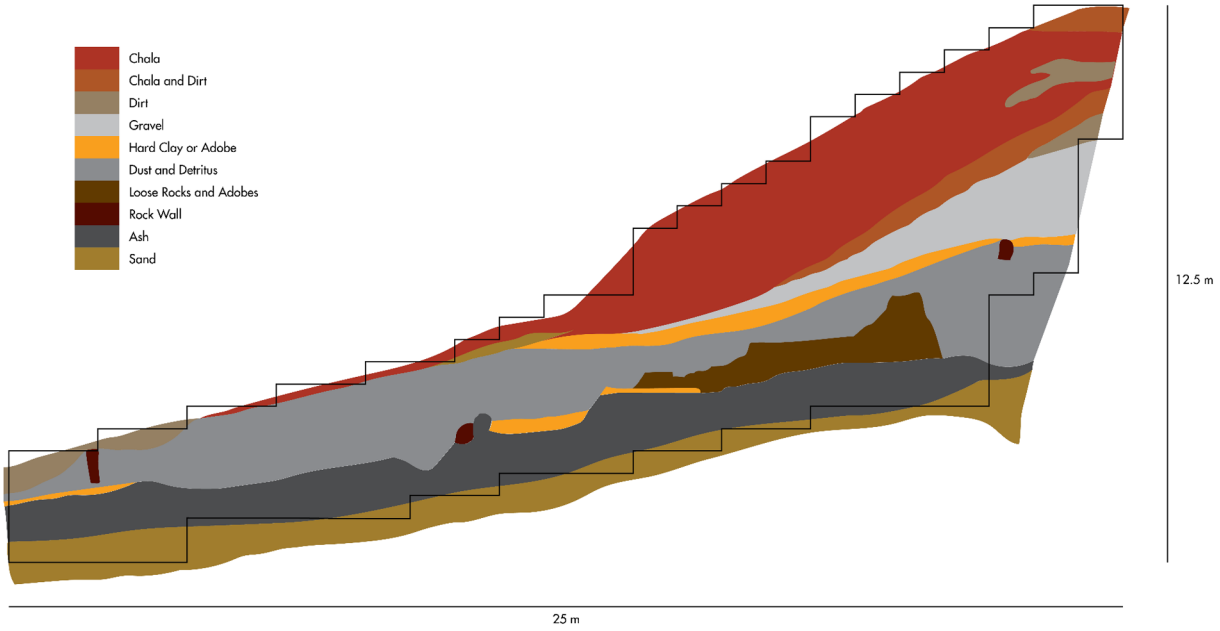

Fig. 4. Schematic outline of Cut 2 blocks, with stratigraphic layers observed during excavations. After Strong et al. (1943:43), Fig. 5.

styles and their attributes led to occasional misassignments, especially between "Inca Associated" and "Interlocking" categories.

At the American Museum of Natural History, 472 ceramic artifacts from this collection were analyzed for a number of qualitative and quantitative attributes related to their form and decoration (Table 1). This number is regrettably smaller than the total number of artifacts excavated; however many of the diagnostic artifacts were sent to other museums as type collections in exchanges during the 1940s, and the remainder of the collection is uncatalogued and inaccessible to researchers. Material from this collection that is catalogued is stored in boxes by type (e.g., a box of *urpu* sherds) irrespective of excavation block information. Sampling for this study was limited by these restrictions. From artifacts available for research, the sample was selected through preferencing any Inka or more recent material, as well as forms (plates, jars, and bowls) typically used for serving which are also the most common forms in this assemblage.

Table 1
Attributes of ceramic artifacts analyzed for this study.

Attribute	Description
Rim Diameter	Measured using a rim diameter chart in centimeters
Wall Thickness	Measured using calipers in millimeters
Wall Angle	Measured from rim profile drawing in degrees
Rim Form	Rounded, Squared, Pointed, or Lipped
Wiping/Scraping	Presence and Location
Slip	Presence and Location
Burnishing	Presence, Location, and Direction
Incising	Presence and Location
Fire Clouds	Presence and Location
Paint	Munsell values for colors, Location, and Scheme
Wear	Presence and Location

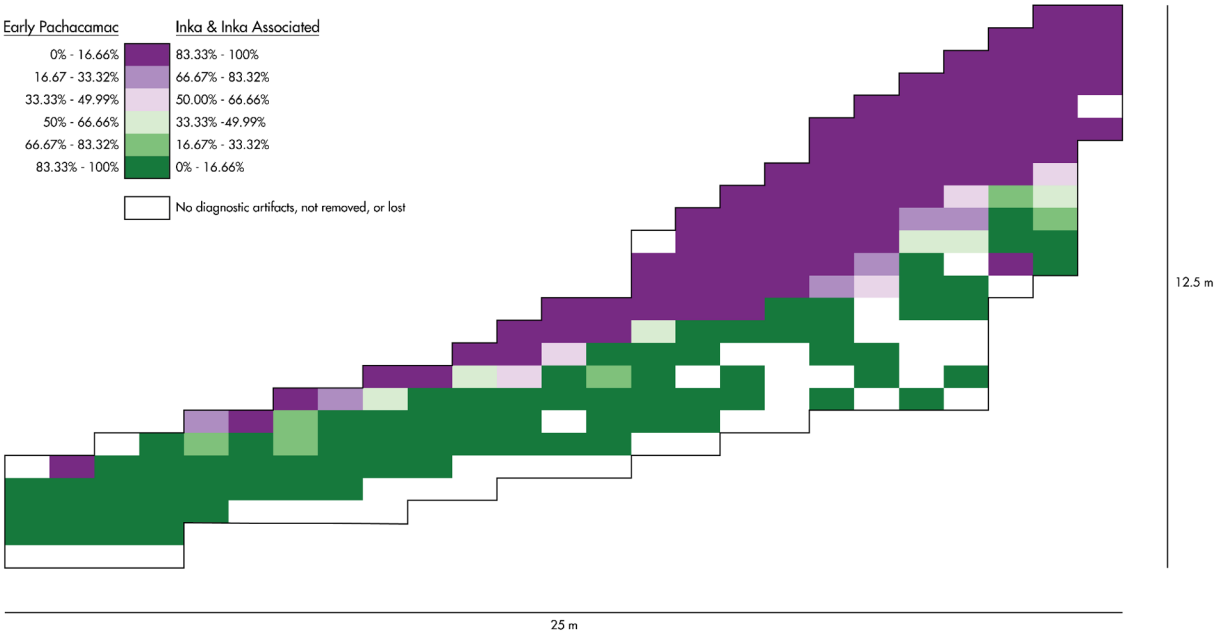

Fig. 5. Percentages of Inka/Inka-Associated and Early Pachacamac style ceramic artifacts by excavation block. Based on data from Strong et al. (1943).

Table 2
Counts of ceramic forms from the collection that was analyzed and what is included in this study. Categories for Inka Polychrome, Regional Inka, and Local Styles roughly correspond to Strong et al.'s (1943) categorizations of the ceramic styles, however some artifacts that were assigned to "Inca Associated" and "Interlocking" by Strong were mis-identified and reassigned to the correct groups prior to this analysis.

	Total Collection	This Study	Group 1	Group 2	Group 3	Outliers
Open Forms	181	56	15	29	1	6
Plates	*98*	*47*	*12*	*28*	*1*	*6*
Bowls	*60*	*7*	*6*	*1*		
Closed Forms	273	93	53	25	10	10
Urpus	*80*	*24*	*2*	*10*	*10*	*5*
Indeterminate	18					
Inka Polychrome	164	65	9	34	11	10
Regional Inka	234	28	4	21		2
Local Styles	69	56	54			4
Total	472	149	67	55	11	16

4.2. Neutron activation analysis

A sample of 149 artifacts from the analyzed collection were evaluated using neutron activation analysis (NAA) at the University of Missouri Research Reactor (MURR). This sample was chosen based on several criteria: (1) representation from each of the three categories identified by Strong ("Inca," "Inca Associated," and "Interlocking"); (2) representation of the forms present in the larger sample of analyzed pottery; and (3) to have representation from multiple locations within "Cut 2" from blocks excavated from different stratigraphic descriptions. Earlier "Interlocking" material was included to identify for what is "local" in the absence of clay sources. The sample was chosen to be roughly representative of the distributions of the total artifacts analyzed, keeping in mind the biases in what was collected and what is curated (Table 2).

The main goal of compositional analysis is to identify distinct homogeneous groups within the analytical database. NAA is a bulk compositional analysis, meaning that pastes, including clays and aplastic inclusions like temper, are homogenized prior to evaluation. These groups may be assumed to represent distinct sources of materials (Weigand et al., 1977). When samples from the source material are not available, indirect methods such as the criterion of abundance can be used (Bishop et al., 1992). Procedures for NAA at MURR are described elsewhere in detail (Glascock, 1992, 2019). To briefly summarize, a section roughly 2 cm^2 in area was removed, and all surfaces of the sherd were scraped off using a tungsten-carbide drill burr to account for glazing or slipping of the surface, contamination during use, and surface leaching or contamination during the artifact's time in the soil (Glascock, 1992:13). The scraped piece was brushed clean and washed in deionized water, dried, and then crushed into powder using an agate mortar and pestle. The powder was dried in an oven at 100 °C for 24 h and stored in a desiccator before being put into a 2/5-dram high-density polyethylene vial and irradiated for five seconds. After 25 min passed, the samples were placed a fixed distance away from a high-resolution germanium detector, which counts the emitted gamma rays for 12 min, allowing determination of the yields of the elements Al, Ba, Ca, Dy, K, Mn, Na, Ti and V. Two weeks later, the samples were transferred to a high-purity quartz vial and irradiated for 24 h. After seven additional days, the vials were washed with nitro-hydrochloric acid, placed in test tubes, and counted for 2000 s, allowing the determination of As, La, Lu, Nd, Sm, U and Yb. Four weeks later, the samples were counted again for 10,000 s, allowing the determination of Ce, Co, Cs, Eu, Fe, Hf, Ni, Rb, Sb, Sc, Sr, Ta, Tb, Th, Zn and Zr. During this process, known reference standards of SRM-1633a (coal fly ash), SRM-688 (basalt rock), SRM-278 (obsidian rock), and Ohio Red Clay (a standard developed for in-house applications) were also sampled to ensure that the process was accurate (Glascock, 1992).

There is much detailed discussion of the interpretation of compositional data from archaeological ceramics (e.g., Baxter and Buck, 2000; Bieber et al., 1976; Bishop and Neff, 1989; Glascock, 1992, 2019; Harbottle, 1976; Neff, 2000). Statistics were performed and groups were formed from only the 149 samples evaluated at MURR. Preliminary groups were formed through a combination of bivariate and multivariate techniques, including hierarchical cluster analysis, scatter plots, and principal components analysis (Baxter, 1992; Baxter and Buck, 2000; Neff, 1994, 2002). Group membership was then refined to create statistically homogenous core groups based on the multivariate probability of group membership, calculated using Mahalanobis distance (Bieber et al., 1976; Bishop and Neff, 1989). Lastly, non-core members were either assigned to groups or assigned as outliers based on discriminate function analysis and other measures of group membership (Glascock, 1992).

4.3. Attribute analysis

After compositional groups were identified using the analyses described above, the groups were examined and compared. Groups were first evaluated for styles (using the categories Inka Polychrome, Regional Inka, or "Local" styles including both earlier Lima and Nievería and later Ychsma) and forms (closed forms like bottles, jars (such as *urpus*) and ollas, and open forms including plates, and shallow bowls) using chi-squared goodness of fit tests to determine if any groups were significant in these variables. For this analysis, "Regional Inka" is defined as vessels which combine aspects of Inka Polychrome (e.g., form, or design elements) with styles local to the central coast or elsewhere, including the north-central coast (Chancay-Inka) or the north coast (Chimú-Inka), both of which are present at Pachacamac. For the chi-squared goodness of fit tests, P values were set at 0.05. Statistical comparisons were then made of attributes across groups. These comparisons determined whether there were any attributes related to either production or decoration that corresponded with distinctions in group membership, especially between similar styles and forms in different compositional groups. Quantitative values (rim diameter, wall thickness, wall angle) were analyzed using Model II one-way ANOVA tests (Van Pool and Leonard, 2011:154). Qualitative attributes were analyzed using chi-squared goodness of fit tests. P values were set at 0.05.

4.4. Comparative data from the Lawrence Berkeley National Laboratory

Between the 1960s and 1990s, the Lawrence Berkeley National Laboratory (LBNL) in Berkeley, California analyzed over 12,000 archaeological and geological samples using neutron activation analysis and X-ray fluorescence (Asaro and Adan-Bayewitz, 2007; Boulanger, 2012). Included in this number were 166 archaeological ceramics from Peru. These ceramics range broadly in time period and location and were contributed to LBNL for analysis either from the Phoebe A. Hearst Museum of Anthropology (then called the Lowie Museum of Anthropology), or from contemporary archaeological projects in Peru. These data have been digitized and uploaded to the Digital Archaeological Record (tDAR) by Matthew Boulanger (Boulanger and Lawrence Berkeley National Laboratory, 2014). In digitizing these data, Boulanger (2012, 2013) has made available descriptive information about the artifacts, including time period and style, as well as photographs (Boulanger and Lawrence Berkeley National Laboratory, 2011).

Of the 166 archaeological ceramics from Peru that were analyzed at LBNL, there are 43 that provided an interesting point of comparison with the data from Pachacamac presented in this study. Thirteen sherds from Cuzco in Inka Polychrome style were evaluated at LBNL. These sherds were collected from Saqsaywaman or from the surface around the city by Max Uhle and were from the collections of the Hearst Museum. Additionally, LBNL analyzed 14 sherds from the Strong

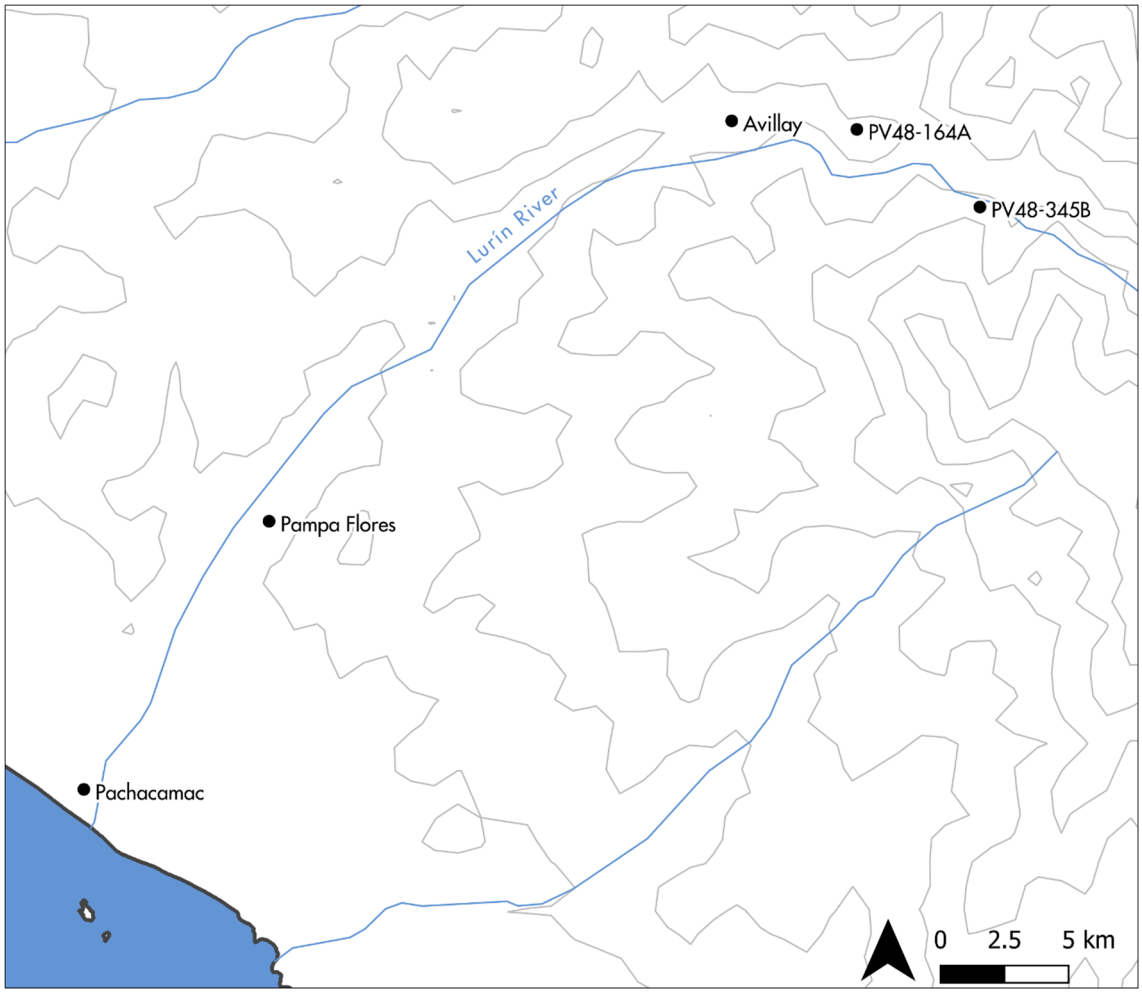

Fig. 6. Sites in the Lurín valley from which archaeological ceramics were analyzed using NAA at LBNL.

excavations at Pachacamac that were sent to the Hearst Museum from the American Museum of Natural History in an artifact exchange. The material from Pachacamac analyzed by LBNL is primarily Inka Polychrome. Also of interest to this study are 16 sherds from four sites upriver in the Lurín valley that were collected by Thomas C. Patterson and the members of the Lurín Valley Project (Fig. 6; Feltham, 1983; Loffler, 2018). These sherds are either Inka Polychrome or local styles and are (from west to east) four from Pampa Flores (PV48-12), four from Avillay (PV48-137B), five from PV48-164A, and three from PV48-345B. From an analysis of surface ceramics, these sites all were occupied during the Late Intermediate Period and Late Horizon, and Avillay and PV48-164A had surface ceramics in Colonial styles as well (Loffler, 2018). The route between Pachacamac and another major Inka center, Hatun Xauxa, passes through the Lurín valley and through these sites. Pampa Flores was an Ychsma political center 14 km northeast of Pachacamac that saw significant Inka presence; ~10% of diagnostic ceramics examined at the site were Inka or Inka-associated styles (Capriata et al., 2016:199). Avillay is a settlement associated with a hilltop shrine that may have been constructed by the Inka (Cornejo, 1995).

The data from LBNL are comparable to data collected at MURR using conversion factors calculated by MURR in an intercalibration exercise (Glascock, 2019:5). Previous comparisons between data from the two labs have been successful (Burger et al., 2019). Data from LBNL do not include all the elements that are detected through NAA at MURR. Missing from the LBNL data are counts for Al, V, Sr, Zr, and Nd. Statistical methods applied to form groups and determine group membership probabilities for the data from MURR were calculated including these elements, but they were removed before comparison between the two datasets was made. In order to visually compare these datasets, a separate Principal Components Analysis was calculated only on the 149 samples run at MURR but without the values for elements not present in the LBNL.

5. Results

Three distinct compositional groups were identified (Figs. 7 and 8; Table 2). Sixteen ceramic artifacts (10 Inka Polychrome, 2 Regional Inka, and 4 in local styles) are outliers and could not be assigned with certainty to any group. Data can be found in Appendix A. Group membership probabilities based on Mahalanobis distance can be found in Appendix B.

Results from Principal Component Analysis (Fig. 9) indicated that the elements that are positively loaded for PC#1 are Cs, As, and Sb; for PC#2, La, Ce, Cr, Ta, and Th; and for PC#3, Na, K, and Ba. Because NAA is a bulk compositional analysis and these data include both clays and aplastic inclusions, the elemental differences that define the groups may be a result of either different clay sources or different proportions of clay and temper. The geology of the lower Lurín valley is a mix of shales, sandstones, and clay deposits with intrusive igneous outcroppings of andesite, granodiorite, and tonalite (León and De La Cruz, 2003). The importance of these elements in defining groups and their concentration in the data (Appendix A) supports these being trace elements present in clays, and the groups founded on utilization of different clay sources rather than the use of different tempers or ratios of tempers and clays.

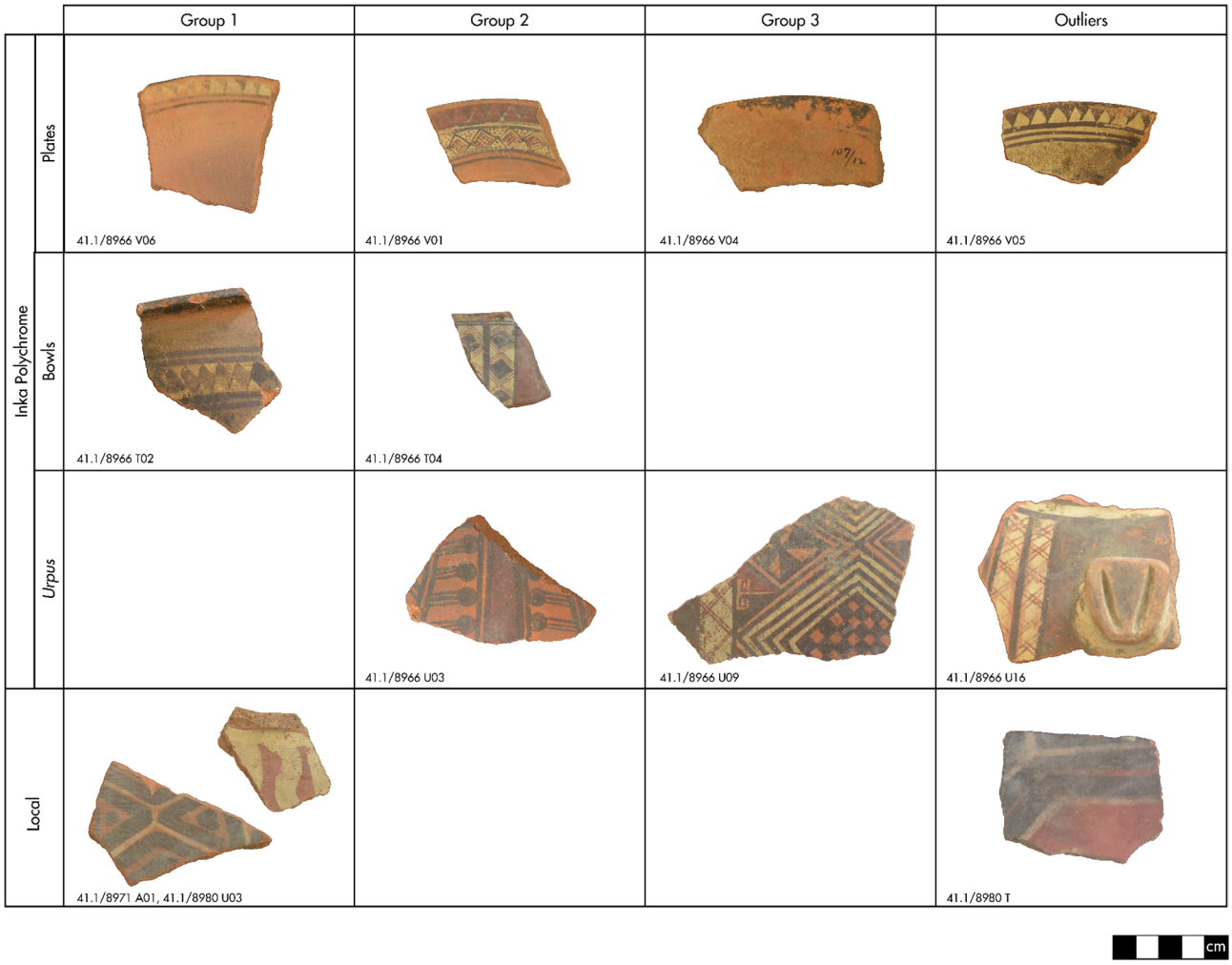

Fig. 7. Examples of pottery from each group. Courtesy of the Division of Anthropology, American Museum of Natural History.

5.1. Group 1

Group 1 is comprised of 67 sherds. A majority of this group (n = 54, 80.5%) are local styles. Nine are Inka Polychrome and an additional 4 are Regional Inka. Of the 13 Inka Polychrome and Regional Inka members of Group 1, 10 are open forms (7 plates and 3 bowls) and 3 are closed forms (all in local styles of indeterminate forms).

5.2. Group 2

Group 2 is comprised of 55 sherds. There are no local styles present in this group, and 34 are Inka Polychrome while the remaining 21 are Regional Inka. This group contains 30 (54.5%) open forms and 25 (45.5%) closed forms. Of the open forms, 29 are plates and one is a bowl. There are 7 *urpus* and 18 closed form sherds of indeterminate forms.

5.3. Group 3

Group 3 is comprised of 11 sherds. All sherds in Group 3 are Inka Polychrome, there are no local or Regional Inka styles present. This group contains 1 open form, a plate. The other 10 (90.9%) members of this group are *urpus*.

5.4. Comparative data

Several trends are evident when comparing data from Pachacamac ceramics with data from LBNL. Ceramics from Pachacamac that were analyzed at LBNL plotted primarily within groups identified at MURR (Fig. 10), demonstrating the comparability of these data collected at different labs. Additionally, some of the ceramics from other sites in the Lurín valley (Pampa Flores, Avillay, and PV47-164A) analyzed at LBNL fit within Groups 1 and 2 (Fig. 10). Lastly, ceramics from Cuzco plotted entirely separate from these groups (Fig. 11).

A previous study which compared these data to compositional data collected at MURR from the Cuzco region found that a sherd from Pachacamac and a sherd from Avillay analyzed at LBNL had compositional similarity to a group from Cuzco (Burger et al., 2019:109). Treating the LBNL Cuzco data as a group, one *urpu* outlier from this study fits statistically with these data (catalog no. 41.1/8971 A03, labeled on Fig. 8).

Though direct comparison is not possible, it is still worthwhile to compare the results of this research with those from recent work comparing ceramics from the Lurín valley and clay sources from several valleys on the central coast (Makowski and Oré, 2014; Makowski et al., 2008, 2015). That research, which evaluated only clays and not pastes using LA-ICP-MS, identified three distinct compositional groups which contained variation in decorative style as well as in macroscopic pastes, potentially indicating different potting practices or technologies were employed using the same clay. In PCA of these data, the authors identified K, Fe, Cu, Zn, As, Rb, Sr, Sb, Cs, Ba, Hf, Pb, and U as the elements that best discriminate the three groups (Makowski et al., 2008:276). Not all of these elements were detected using NAA, however of those that were, many of the same elements contributed strongly to variance in this research. It is likely that clay sources in the lower and

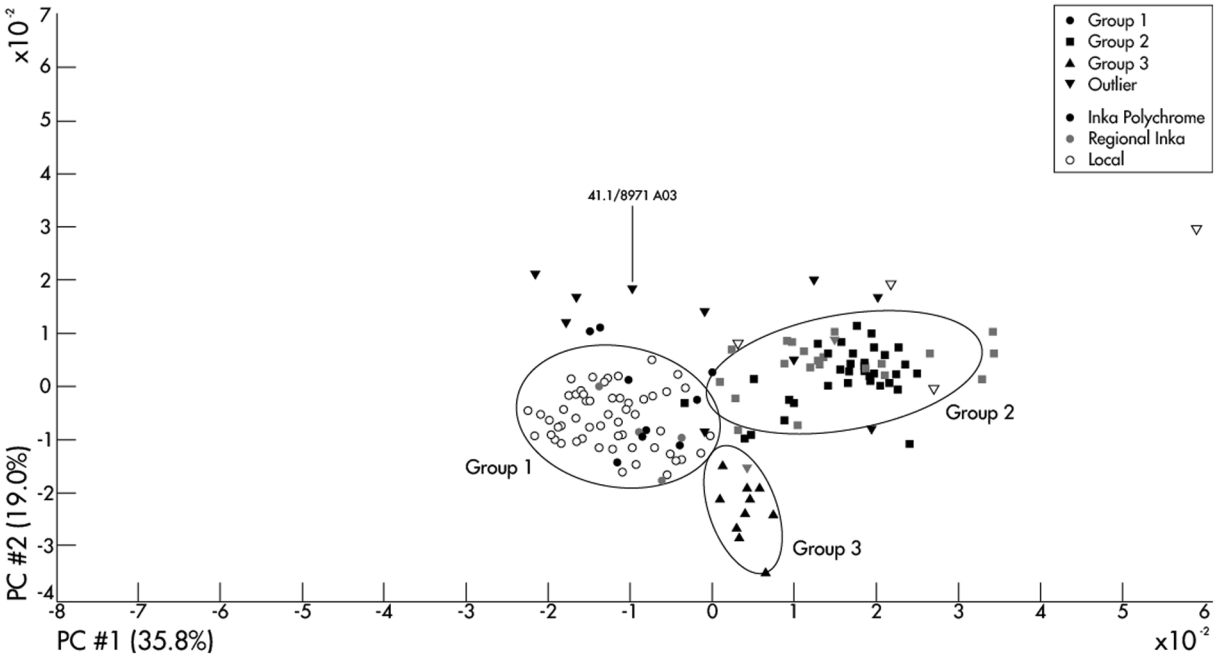

Fig. 8. Bivariate plot of neutron activation analysis data using Principal Components Analysis. Circles are members of Group 1, squares are members of Group 2, triangles are members of Group 3, and upside-down triangles are outliers which could not be assigned to any group. Black points are Inka Polychrome sherds, grey points are Regional Inka, and white are local styles. Ellipses represent 90% confidence intervals. This figure is presented at the same scale as Figs. 10 and 11 to allow for comparison between them. The outlier ceramic artifact with catalog no. 41.1/8971 A03, most likely to be from Cuzco, is labeled.

middle Lurín valley (and possibly the Rimac valley) that were tied to compositional groups in Makowski et al.'s (2015:150) study were also utilized to produce the pottery analyzed by this study.

5.5. Statistical analysis of attributes

After groups were identified, statistical evaluations were made to determine if there were any attributes, stylistic or metric, that corresponded with group membership. In a chi-squared goodness of fit test, the distribution of Inka Polychrome and Regional Inka plates, *urpus*, and bowls across the groups was found to be significant ($p \leq 0.001$). While no form is only found in a single compositional group, each group contains a form in a higher proportion than the others (bowls in Group 1, plates in Group 2, *urpus* in Group 3). A chi-squared goodness of fit test was made to compare the decoration color schemes of Inka Polychrome (e.g., black, white, and red versus black and white versus white and red, etc.) across the groups and found the distribution to be not significant ($p = 0.735$).

Metric measurements and decorative attributes were also statistically compared among similar Inka Polychrome forms between groups.

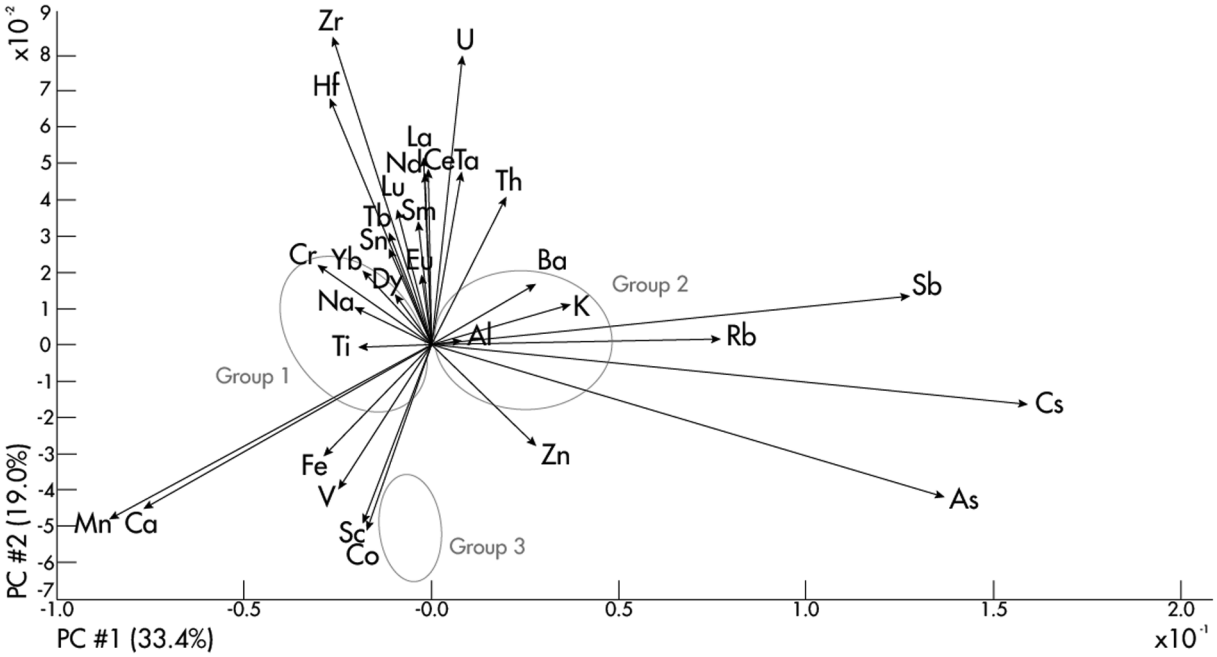

Fig. 9. Principal Components Analysis, calculated with all 32 elements detected at MURR on the 149 samples analyzed at MURR. Vectors correspond to the variance contributed by each element detected. Ellipses represent 90% confidence intervals for Groups 1, 2, and 3.

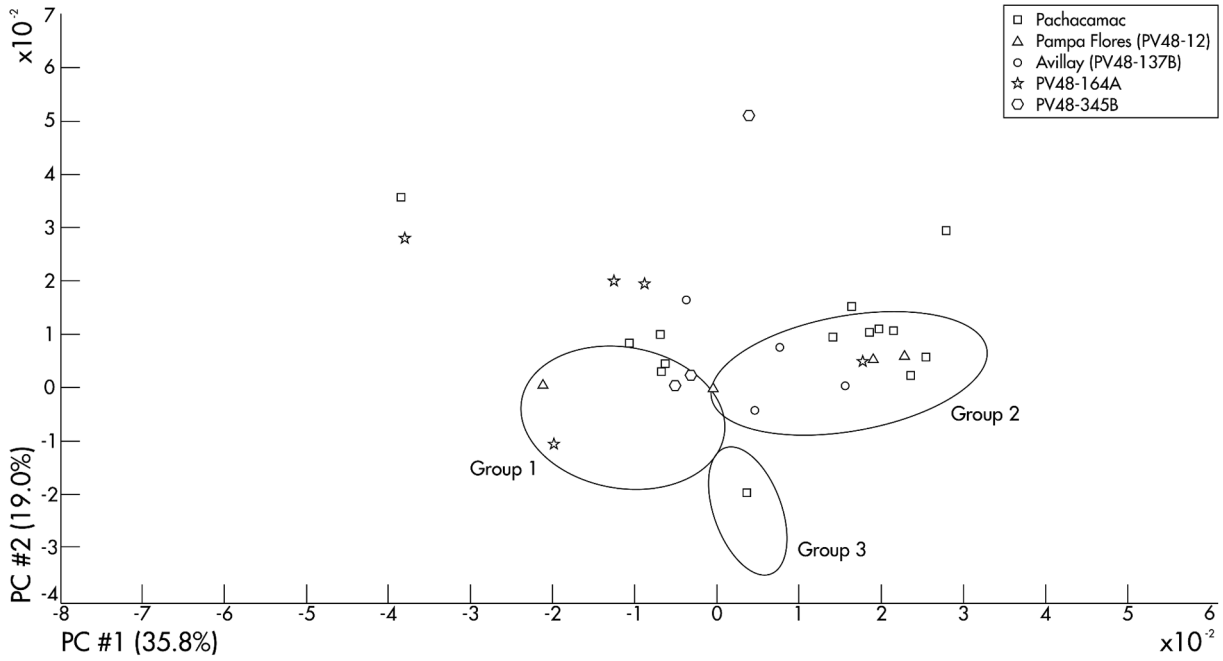

Fig. 10. Data from ceramic artifacts from Pachacamac and four sites in the Lurín valley that were analyzed at LBNL are overlaid over the 90% confidence interval ellipses for the groups from this analysis.

Among plates, no attributes were statistically significant: ANOVA tests for rim diameter, wall thickness, and wall angle and chi-squared goodness of fit tests for rim form, burnishing, incising, fire clouding, and wear for Inka Polychrome and Regional Inka plates showed no statistically significant differences between groups. Similarly, among *urpus*, no attributes were statistically significant when compared across compositional groups.

Decoration was compared between similar forms across the groups in two ways. First, color scheme was recorded as the base color or slip and what other colors were painted on the surface (e.g., black on white, black and white on red, etc.). Second, specific design elements in distinct areas were recorded and compared. These areas are, for plates: the band around the rim (typically a row of triangles pointing inward bounded by one or more lines) and a band across the center, which typically features a type of quatrefoil design. For *urpus*, the areas are: the design on the neck of the vessel (when present), a central band which typically features a type of quatrefoil design, and two panels that flank this central band, which is typically either repeating bands of downward facing triangles or a stylized plant (often called “fern”) design. Attributes of these motifs that were recorded were the colors, shapes, and number of lines of the different elements. There was no color scheme that was unique to any group, and any design motif present in Group 1 was also present in Group 2 (Fig. 12). There were unique designs present in Group 2, though this group contained more Inka polychrome pottery than the others.

The sample size of Inka Polychrome between the groups may be too small for any statistically significant trends to appear, however there is not one attribute, nor metric, nor design pattern or color combination,

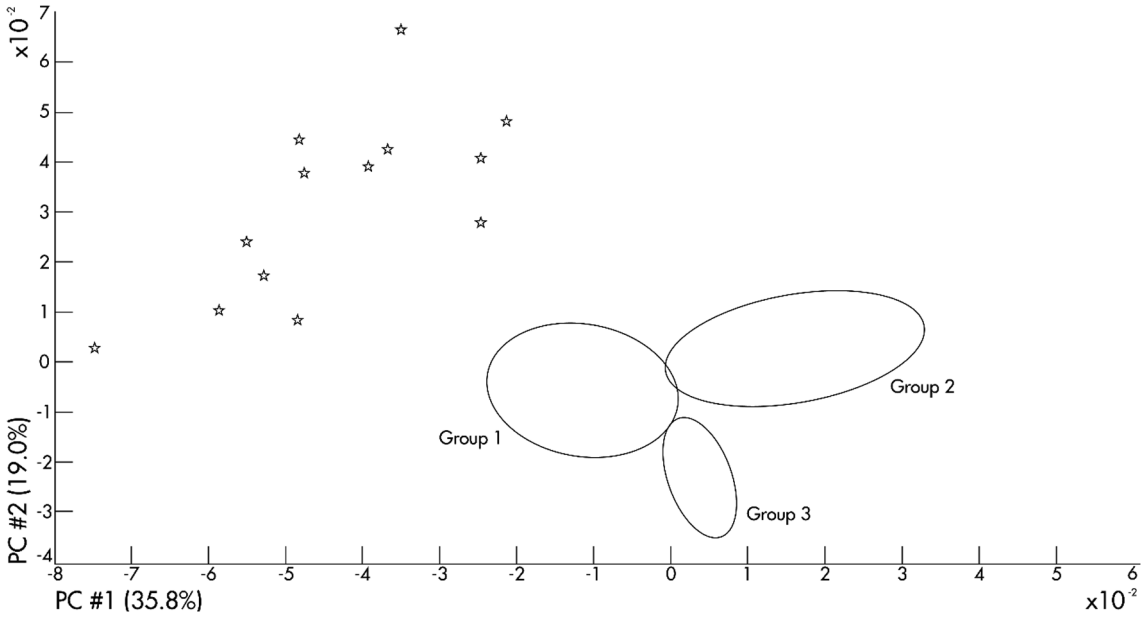

Fig. 11. Data from ceramic artifacts from Cuzco that were analyzed at LBNL are overlaid over the 90% confidence interval ellipses for the groups from this analysis.

Fig. 12. Examples of similar design motifs in Group 1 (AMNH catalog no. 41.1/8966V03) and Group 2 (AMNH catalog no. 41.1/8966N). Courtesy of the Division of Anthropology, American Museum of Natural History.

that can reliably be used to distinguish Inka Polychrome pottery as a member of any of these identified compositional group. It is likely that multiple groups of potters were producing this Inka Polychrome pottery. The differences in elemental composition between the groups reflects either differences in location of raw materials, both clay and aplastic additions, or differences in raw material selection and processing, a step of the production process that often varies group to group. Some of the attributes included in this study, such as surface decoration and finishing, are high visibility attributes which can be easily copied or reproduced without communication between potters (Zedeño, 1994).

6. Discussion and conclusions

Inka Polychrome pottery was critical for the state to enact reciprocity in its provinces. It was distributed and produced widely by subject potters throughout the empire. In examining the ceramic assemblage from the Inka-built Temple of the Sun at Pachacamac, several conclusions can be drawn about how production was organized.

First, Inka Polychrome pottery was produced locally, either at Pachacamac or elsewhere in the Lurín valley. Pottery production workshops or locations have been hypothesized (e.g, Menzel, 1964, 1977) but have not been located archaeologically. Though raw material sources from these places were not included in this study, compositional similarity between local styles and Inka Polychrome pottery in Group 1 supports local production. Second, there are multiple groups of potters producing the Inka Polychrome pottery from the Temple of Sun. These groups may have been working at multiple production loci and using compositionally distinct sources of clay or temper. It is also possible that they could have been utilizing the same raw materials but different recipes or methods for processing. Furthermore, it is possible that the same potters were using different processes or technologies to produce different types of vessels. Third, there are no attributes, morphometric or decorative, that can be used to distinguish Inka Polychrome pottery from different compositional groups. There are also no Inka Polychrome forms that are exclusive to any group, however it is possible that there was a preference or bias for producing different Inka Polychrome forms at the different production loci. Lastly, these loci made pottery for both Pachacamac and other sites in the Lurín valley. Archaeological research at several of these sites indicates they settled or expanded by the Inka, and their position along the state road *qhapaq ñan* likely facilitated the movement of pottery between these sites and Pachacamac. While there may have been some movement of pottery between Cuzco and Pachacamac, a large majority of Inka Polychrome pottery that was sampled in this project (~98.5%) was not made in the capital region. Sherds that were statistical outliers to any group may represent importation from other centers of Inka Polychrome pottery production, such as the Chincha valley (including the La Centinela-Tambo de Mora complex) to the south or Hatun Xauxa and Huánuco Pampa in the highlands. Without raw material sources or local styles of pottery as members, Groups 2 and 3 cannot be assigned a location with certainty, though given the number of ceramics within these groups it is likely that they were also produced locally in the central coast.

These conclusions are in accordance with, and build upon, previous work examining the organization of production for pottery of the central coast (e.g., Makowski and Oré, 2014; Makowski et al., 2008, 2015) and for Inka Polychrome (e.g., D'Altroy and Bishop, 1990). The organization was complex. The Inka entrusted multiple groups of potters (some of them local) in multiple places with the creation of Inka Polychrome pottery for the Temple of the Sun at Pachacamac, and imported small amounts of pottery as well. As these objects were necessary for state-sponsored events in the provinces, these data about their production improve the understanding of how the Inka empire provisioned its efforts within its subject territories and populations. Based on these results, potters laboring for the state to produce Inka polychrome pottery may have been a mix of full-time, attached specialists who were either local or relocated *mitmaq* potters, and part-time potters serving labor obligations. While investigation into Inka Polychrome pottery has expanded greatly in recent years, this research highlights a need for continued study into Inka Polychrome pottery's production and use, both at Pachacamac and elsewhere in the provinces. Potters may have been retrained by the Inka empire to create Inka Polychrome pottery. This pottery could have also been produced by *mitmaq* potters relocated to Pachacamac from elsewhere in the empire, or by itinerant potters. Additional investigation into other steps of the production sequence will help in understanding the relationship between subject potters and the state.

CRediT authorship contribution statement

James A. Davenport: Conceptualization, Methodology, Formal analysis, Investigation, Resources, Data curation, Writing - original draft, Writing - review & editing, Visualization, Funding acquisition.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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Appendix A. Supplementary material

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jaa.2020.101235.

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